ENCLOSURE 2 TO NL-13-147

IP-CALC-13-00070, R1

LEAK REPAIR CLAMP EVALUATION FOR LINE 1093 IN 32 MAIN TRANSFORMER MOAT

ENTERGY NUCLEAR OPERATIONS, INC.
INDIAN POINT NUCLEAR GENERATING UNIT NO. 3
DOCKET NO. 50-286

☐ ANO-1 ☐ ANO-2 ☐ GGNS ☐ IP-2 ☒ IP-3 ☐ PLP
☐ JAF ☐ PNPS ☐ RBS ☐ VY ☐ W3
☐ NP-GGNS-3 ☐ NP-RBS-3

CALCULATION COVER PAGE	(1) **EC # 47124** (2) **Page 1 of 5**
(3) Design Basis Calc. ☐ YES ☒ NO	(4) ☒ CALCULATION ☐ EC Markup
(5) **Calculation No: IP-CALC-13-00070**	(6) **Revision: 1**
(7) **Title: Leak Repair Clamp Evaluation for Line 1093 in 32 Main Transformer Moat**	(8) **Editorial** ☐ YES ☒ NO
(9) **System(s): SW**	(10) **Review Org (Department): Civil/Structural**

(11) **Safety Class:** ☒ **Safety / Quality Related** ☐ **Augmented Quality Program** ☐ **Non-Safety Related**	(12) **Component/Equipment/Structure Type/Number:**	
	32 Main Transformer Moat	
(13) **Document Type: CALC**		
(14) **Keywords (Description/Topical Codes):**		

REVIEWS

(15) Name/Signature/Date	(16) Name/Signature/Date	(17) Name/Signature/Date
Kai Lo 10-30-2013 [signature]	G. Bhalla [signature] 10/30/13	R. Drake [signature] 10/31/13
Responsible Engineer	☒ **Design Verifier** ☒ **Reviewer** ☐ Comments Attached	**Supervisor/Approval** ☐ Comments Attached

CALCULATION REFERENCE SHEET	CALCULATION NO: IP-CALC-13-00070 REVISION: 1

I. EC Markups Incorporated (N/A to NP calculations)
None

II. Relationships:	Sht	Rev	Input Doc	Output Doc	Impact Y/N	Tracking No.
1.			☐	☐		
2.			☐	☐		

III. CROSS REFERENCES:

1. IP3 Piping Specification, TS-MS-027
2. USAS B31.1, Power Piping Code, 1967 edition
3. Drawing 9321-22363 (Piping)
4. IP3-UT-13-058
5. ANVIL Catalog
6. CR-IP3-2013-04174
7. CR-IP3-2013-04416
8. IP3-VT-13-021

IV. SOFTWARE USED:

Title:__________ Version/Release:______ Disk/CD No.______

V. DISK/CDS INCLUDED:

Title:__________ Version/Release______ Disk/CD No.______

VI. OTHER CHANGES: None

Revision	Record of Revision
0	Initial issue.
1	Revised calculation due new flaw length

Total number of pages: 15

5.0 Purpose

In the moat of the 32 transformer yard, an area was identified of missing metal of the pipe wall thickness due to external surface corrosion. The degraded pipe location is in the ISI Class 3 code boundary (See CR-IP3-2013-04174). CC-N-513-3 was invoked and the degraded piping is structurally adequate. A red rubber patch will be placed on the defective pipe surface held tight to prevent any potential water leakage by means of a pipe clamp. The following pipe stress evaluation is needed due to the addition of the pipe clamp and the large flaw size:

1. The additional weight of the clamp on the pipe stress.
2. The clamping pressure acting on the pipe.
3. Ensure the compressive clamping pressure is greater than the pipe's design pressure to prevent water from leaking out.

6.0 Conclusion

The additional weight of the pipe clamp onto the piping will result in insignificant increase of pipe stress. Based on the VT report, a 12"x6" red rubber pad, 1/4" for the thickness of the rubber pad, and 1/16" maximum compressive deformation of the rubber pad, the compressive pipe membrane stress will be below the allowable stress limit. The compressive pressure is greater than the pipe's design pressure and water cannot leak out.

7.0 Input and Design Criteria

1. Piping material: A53 Gr B, schedule 40 per specification TS-MS-027
2. Allowable pipe stress and piping code: S_h = 15 ksi, B31.1Power Piping Code, 1967 edition
3. An average Durometer hardness of 70 for red rubber material.
4. 8" wide pipe clamp from Figure 432 of ANVIL catalog.

8.0 Assumptions

1. Actual weight of the pipe clamp is less than 18 lbs, but 25 lbs is used conservatively.
2. Fig. 432 pipe guide is used as a clamp.
3. A 12" x 6" red rubber pad is a placed at the defective externally corroded area.
4. The thickness of the red rubber is 1/4".
5. 1/16" compression of the red rubber pad is allowed to limit the compressive stress on the pipe.

9.0 Method of analysis

The stress of the pipe induced by the clamping force is evaluated using case 17 from table 30 of Roark's "Formulas of Stress and Strain".

10.0 Calculation

See Attachment I

Attachment I

Calculation

Determine the additional bending stress induced by the additional pipe clamp

W = weight of clamp =	25	lb (cons)	
p = design pressure =	150	psi	
d = outside diameter =	10.75	in	
t = nominal wall thickness =	0.365	in	
S = section modulus =	29.9	in^3	
L = pipe span =	8	ft =	96 in
Sh = allowable stress =	15000	psi	

Conservatively consider the pipe is pinned at support ends

Ma = moment due to DW = WL/4 =	600	in-lb	
fb = bending stress = Ma/S =	20	psi	
fb/Sh = ratio of additional stress to the allow limit =	0.13%	, negligible	

Determine the compressive stress induced by the clamping force

S_A = Durometer Shore A hardness of red rubber =	70		
log E = $0.0235S_A$ - 06403 =	1.0047		
E = modulus of elasticity =	10.11	MPA =	1466 psi
w = width of ruber pad axially =	6.0	in	
l = bearing length circumferentially =	12.0	in	
t' = thickness of red rubber pad =	0.25	in	
δ = deformation due to compression =	0.0625	in	
A' = defective surface area externally corroded = 2.5"(8.25") =	19.0	in^2	
A = area of pad being compressed = wl - A' =	53.00	in^2	
P = compressive force acting on the rubber pad = δAE/t' =	19427	lb	

Using the case 17 from Table 30 of Roark's "Formulas of Stresses and Strain"

v = poisson ratio =	0.3		
E = modulus of elasticity =	2.79E+07	psi	
R = mean pipe radius = 0.5(d - t) =	5.1925	in	
$\lambda = [3(1-v^2)/(R^2t^2]^{0.25}$ =	0.934	in^{-1}	
$D = Et^3/[12(1-v^2)]$ =	124240	in-lb	

The external uniform compressive pressure will be offset by the 150 psi internal pressure

q = external uniform pressure = P/A - p =	217	psi	
a = w/2 =	3.0	in	
λa =	2.801		
At x = 0, Max $M = (q/2\lambda^2)e^{(-\lambda a)}\sin(\lambda a)$ =	2.52		
σ'_1 = meridional bending stress = $-6M/t^2$ =	-113	psi < Sh = 15000 psi, o.k.	
σ'_2 = circumferential bending stress = $v\sigma'_1$ =	-34	psi	
At x = 0, Max $y = (-q/4D\lambda^4)[1 - e^{(-\lambda a)}\cos(\lambda a)]$ =	-0.0006	in	
σ_2 = circumferential membrane stress = $yE/R + v\sigma_1$ =	-3291	psi < Sh = 15000 psi	

Since external clamping pressure is compressive, greater than the pipe's design pressure, water will not leak out.

The minimum wall thickness required for the pipe's hoop stress is 0.054" per IP3-CALC-13-00062.

The thickness of the pipe clamp is 3/16", more than adequate to hold the pipe pressure.

Attachment II

Miscellaneous Reference Information

Visual Exam of Equipment and Components (VT-3)

Entergy

Site/Unit:	IP3 / 3	Procedure:	CEP-NDE-0903	Outage No.:	N/A
Summary No.:	SW Line 1093	Procedure Rev.:	5	Report No.:	IP3-VT-13-021
Workscope:	BOP	Work Order No.:	00350692-31	Page:	1 of 1

Code: ANSI B31.1, 67 - 69 ED Cat./Item: N/A Location: Unit #3 Moat Excavation.

Drawing No.: 9321-F-22363 Description: Visually Examine 10" Line #1093 After Removal of Support.

System ID: Service Water

Component ID: 10" SW Line #1093

Limitations: Limited Room on the Bottom Side of the Pipe.

Resolution: 0.105" Character Card Surface Condition: In Service

Light Meter Mfg.: N/A Serial No.: N/A Illumination: SAT

Light Verification Times: Cal In ☐ N/A / N/A / N/A Cal Out ☐ N/A

Visual Equipment/Aids: Flashlight, Mirror, Camera, Tape Measure

Lo Location: Top of Pipe Wo Location: Centerline of the eroded area

Visual Examination: Direct

Loc L	Loc W	Loc U/D	Ind. R/L	Size D/L	Remarks
8.5"	0"	N/A	Linear	8.25" x 2"	See comments below, the remainder of the exposed pipe was in good condition with no corrosion

Comments:

Further Examination of Line No. 1093 revealed that the corroded area originally found extended underneath the pipe to the area that was resting on the wood support. Area measures 8-1/4" circumferentially and 2" wide in the axial direction.

Results: Accept ☐ Reject ☑ Info ☐ Ref CR-IP3-2013-04416 and IP3-UT-13-058

Percent Of Coverage Obtained > 90%: N/A Reviewed Previous Data: Yes

Examiner Level II Peterson, Joseph F.	Signature: [signature]	Date 10/29/2013	Reviewer N/A	Signature	Date
Examiner Level N/A	Signature	Date	Site Review Robert Allen	Signature: [signature]	Date 10/30/13
Other Level N/A	Signature	Date	ANII Review N/A	Signature	Date

Supplemental Report

Entergy

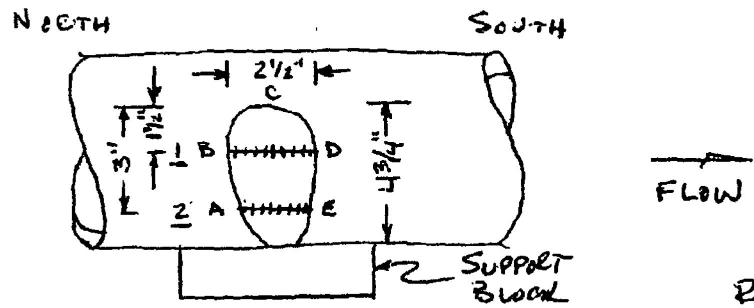
Report No.: IP3-UT-13-058

Summary No.:	10" Line # 1093						
Examiner:	Allen, Robert E. [signature]	Level:	III EOI	Reviewer:	N/A	Date:	
Examiner:	N/A	Level:	N/A	Site Review:	[signature]	Date:	10/3/2013
Other:	N/A	Level:	N/A	ANII Review:	N/A	Date:	

Comments: **Area 3 UTT and pit gage readings.**

Sketch or Photo: \\Client\Y$\Iddeal Ver 8\Iddeal_Server\IDDEAL_IP3\Graphics-Pictures\Service Water\10 in Line 1093 Area 3.TIF

AREA 3



PIT GAGE READING @ 1/4" SPACING:

Row	1/4"	1/2"	3/4"	1"	1 1/4"	1 1/2"	1 3/4"	2"	2 1/4"
1	1/32"	1/16"	3/16"	1/4"	3/8"	3/8"	5/16"	3/16"	1/32"
2	1/64"	1/16"	7/32"	5/16"	3/8"	5/16"	3/16"	1/32"	—

UTT READINGS:

A - .387"
B - .387"
C - .380"
D - .378"
E - .378"

Visual Exam of Equipment and Components (VT-3)

Entergy

Site/Unit: IP3 / 3 | Procedure: CEP-NDE-0903 | Outage No.: N/A

Summary No.: SW Line 1093 | Procedure Rev.: 5 | Report No.: IP3-VT-13-021

Workscope: BOP | Work Order No.: 00350692-31 | Page: 1 of 1

Code: ANSI B31.1, 67 - 69 ED | Cat./Item: N/A | Location: Unit #3 Moat Excavation.

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System ID: Service Water

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Limitations: Limited Room on the Bottom Side of the Pipe.

Resolution: 0.105" Character Card | Surface Condition: In Service

Light Meter Mfg.: N/A | Serial No.: N/A | Illumination: SAT

Light Verification Times: Cal In ☐ N/A / N/A / N/A Cal Out ☐ N/A

Visual Equipment/Aids: Flashlight, Mirror, Camera, Tape Measure

Lo Location: Top of Pipe | Wo Location: Centerline of the eroded area

Visual Examination: Direct

Loc L	Loc W	Loc U/D	Ind. R/L	Size D/L	Remarks
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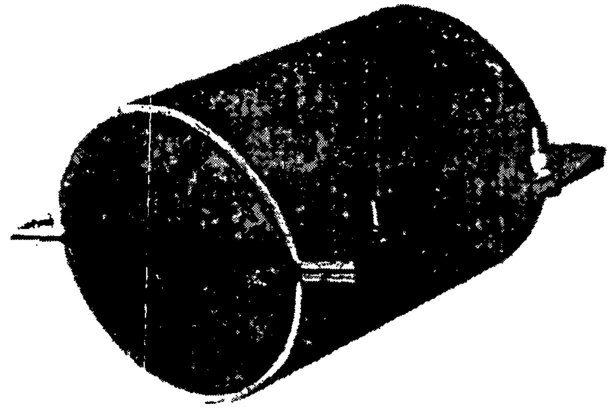
Percent Of Coverage Obtained > 90%: N/A | Reviewed Previous Data: Yes

Examiner	Level	Signature	Date	Reviewer	Signature	Date
Peterson, Joseph F.	II	[signature]	10/29/2013		N/A	
Examiner	Level	Signature	Date	Site Review: Robert Allen	[signature]	10/30/13
Other	Level	Signature	Date	ANII Review	N/A	

Fig. 432

Special Clamp

Size Range: 2" through 24"
Material: Carbon steel
Finish: Plain or Galvanized
Maximum Temperature: Plain 750° F, Galvanized 450° F for carbon steel pipe only
Service: Used with and where pipe slides cannot be welded directly to pipe or copper tube. When used with fiberglass, plastic, or aluminum pipe, a thin protective liner should be inserted between the pipe and the clamp. Clamp is designed for use with Figure 257 and Figures 436 and 439 slides and tees.
Ordering: Specify figure number, pipe size, name and finish.



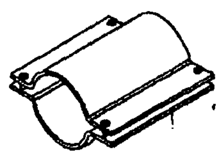


Fig. 257
w/Fig 432 Clamp

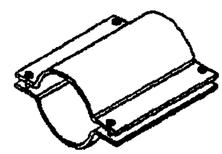


Fig. 436
w/Fig 432 Clamp

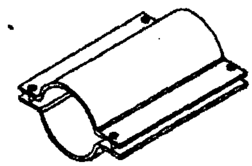
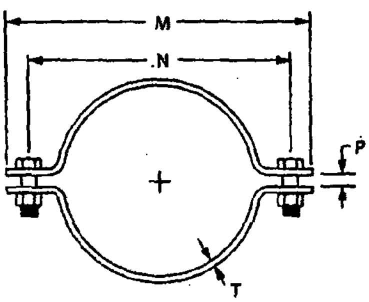


Fig. 439
w/Fig 432 Clamp



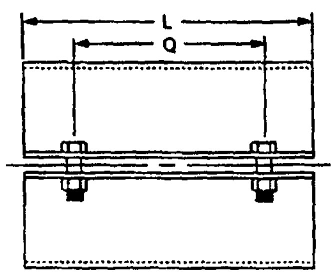


FIG. 432: WEIGHT (LBS) • DIMENSIONS (IN)

Pipe Size	L	M	N	P	Q	T	Weight
2	6	5	4	¼	4½	⅛	2
2½		5½	4½				3
3		6	5				3
3½		6½	5½				4
4		7	6				4
5		8	7				5
6	8	9⅝	8½	⅜	6	3/16	12
8		11⅝	10½				15
10		13¾	12⅝	½			18
12		15¾	14⅝				21
14	12	17⅞	16½			¼	41
16		19⅞	18½		8		46
18		21⅞	20½				52
20		23⅞	22½	⅝			57
24		28⅛	26⅞				67

What is Rubber Hardness?

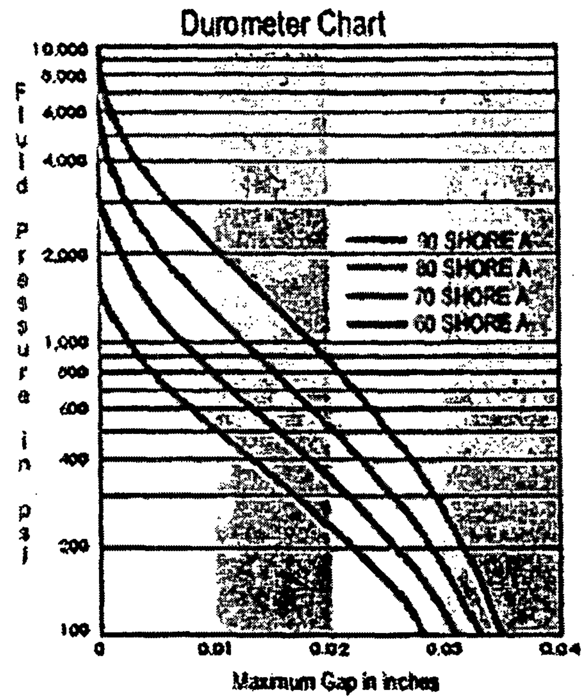
The hardness of rubber compounds is measured by the Shore A durometer; the higher the durometer, the harder the compound. 70-durometer hardness should be used whenever possible as it offers the best combination of properties for most O-Rings applications.

Softer compounds stretch easier and seal better on rough surfaces. Harder compounds offer greater abrasion resistance and resistance to extrusion. Extrusion must always be considered where high pressure is used. The proper hardness may be selected from this chart by matching the fluid pressure with the maximum extrusion gap.

60 Shore A is softer than 70.

70 Shore A is the standard.

90 Shore A is very stiff.



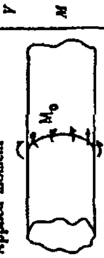
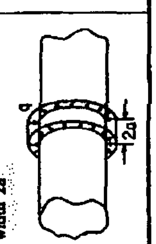
The hardness of an elastomer is measured based on the depth of indentation by a standard size and shape impacting gauge. The hardness is obtained by comparing the difference between a small initial force and a much larger final force. The International Rubber Hardness Degrees (IRHD) scale has a range of 0 to 100, corresponding to elastic modulus of 0 (0) and infinite (100), respectively. The measurement is made by indenting a rigid ball into the rubber specimen.

The Shore A scale is the most prevalent in the United States. The readings range from 30 to 95 points. Harder elastomers use a pointed conical indentor with the Shore D scale. The results of the Shore A scale and the IRHD scale are approximately equal over the same range of resiliency. In elastomers with unusually high rates of stress relaxation or deformation hysteresis, the difference in dwell time in the two readings may cause different results. Also, the results of any hardness test depend on the elastomer thickness. Specified thickness should be used when conducting these tests.

Due to the mechanical limits of the test instruments, hardness measurements of elastomers are rarely expressed more precisely than 5 points.

The surface indentation or hardness usually does not bear any relation to the ability of an elastomeric part to function properly. Hardness is a measure of an elastomer's response to a small surface stress. Stiffness and compressive modulus measure the response to large stresses of the entire elastomeric part.

TABLE 30 *Shear, moment, slope, and deflection formulas for long and short thin-walled cylindrical shells under axisymmetric loading* (Cont.)

Loading and case no.	Load terms or load and deformation equations	Selected values
16. Applied moment 	$V = \frac{-M_o\lambda}{2}e^{-\lambda x}(\cos\lambda x + \sin\lambda x)$ $M = \frac{M_o}{2}e^{-\lambda x}\cos\lambda x$ $\psi = \frac{-M_o}{4D\lambda}e^{-\lambda x}(\cos\lambda x - \sin\lambda x)$ $y = \frac{-M_o}{8D\lambda^2}e^{-\lambda x}\sin\lambda x$	$\text{Max } V = \frac{-M_o\lambda}{2}$ at $x = 0$ $\quad \sigma_1 = 0$ $\text{Max } M = \frac{M_o}{2}$ at $x = 0$ $\text{Max } \psi = \frac{-M_o}{4D\lambda}$ at $x = 0$ $\text{Max } y = -0.0403\frac{M_o}{D\lambda^2}$ at $x = \frac{\pi}{4\lambda}$
17. Uniform pressure over a band of width 2*a* 	Superimpose cases 10 and 12 to make ψ_A (at $x = 0$) = 0	$\text{Max } M = \frac{q}{2\lambda^2}e^{-\lambda a}\sin\lambda a$ at $x = 0$ $\text{Max } y = \frac{-q}{4D\lambda^4}(1 - e^{-\lambda a}\cos\lambda a)$ at $x = 0$ $\sigma_1 = 0$

and $LT_y = 0$ since x is not greater than a. Substituting into the expression for y at $x = a$ gives

$$-0.001 = 0.154(10^{-6})p(-0.07526) - \frac{19.0(10^{-6})p(2.507)}{2(4.0)} = -5.96(10^{-6})p$$

or $p = 168$ lb/in, $y_A = 0.0000259$ in, and $\psi_A = -0.00319$ rad.

Although the position of the maximum moment depends upon the position of the load, the maximum moment in this case would be expected to be under the load since the load is some distance from the free end:

$$M = -y_A 2D\lambda^2 F_3 - \psi_A D\lambda F_4 + LT_M$$

and at $x = a$, $F_3 = 2.37456$, $F_4 = 2.64573$, and $LT_M = 0$ since x is not greater than a. Therefore,

$$\text{Max } M = -(0.0000259)(2)(344)(4.0^2)(2.375) - (-0.00319)(344)(4.0)(2.646)$$
$$= 10.92 \text{ in-lb/in}$$

At the cross section under the load and on the inside surface the following stresses are present:

$$\sigma_1 = 0 \qquad \sigma_1' = \frac{6(10.92)}{0.05^2} = 26{,}200 \text{ lb/in}^2 \qquad \sigma_2 = \frac{-0.001(30)(10^6)}{2.065} = -14{,}500 \text{ lb/in}^2 \qquad \sigma_2' = 0.30(26{,}200) = 7{,}860 \text{ lb/in}^2$$

The small change in the maximum stress produced in this shorter tube points out how localized the effect of a load on a shell can be. Had the radial load been the same, however, instead of the radial deflection, a greater difference might have been noted and the stress σ_2 would have increased in magnitude instead of decreasing.

3. A cylindrical aluminum shell is 10 in long and 15 in in diameter and must be designed to carry an internal pressure of 300 lb/in² without exceeding a maximum tensile stress of 12,000 lb/in². The ends are capped with massive flanges, which are sufficiently clamped to the shell to effectively resist any radial or rotational deformation at the ends. Given: $E = 10(10^6)$ lb/in² and $\nu = 0.3$.

First solution. Case 1c from Table 29 and cases 1 and 3 or cases 8 and 10 from Table 30 can be superimposed to find the radial end load and the end moment which will make the slopes and deflections at both ends zero. Figure 12.4 shows the loadings applied to the shell.

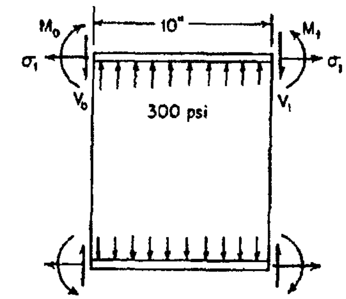


Fig. 12.4

First we evaluate the necessary constants:

$$R = 7.5 \text{ in} \qquad l = 10 \text{ in} \qquad D = \frac{10(10^6)t^3}{12(1 - 0.3^2)} = 915{,}800t^3$$

$$\lambda = \left[\frac{3(1 - 0.3^2)}{7.5^2 t^2}\right]^{1/4} = \frac{0.4694}{t^{0.5}} \qquad \lambda l = \frac{4.694}{t^{0.5}}$$